Formalising the Role of Indigenous Counting Systems in Teaching the Formal English Arithmetic Strategies Through Local Vernaculars: An Example From Papua New Guinea

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In the context of the current education reform in Papua New Guinea which strongly encourages the use of both Indigenous knowledge-based systems and local vernaculars in teaching various school subjects in elementary and primary schools, the research reported here is the first of an on-going longitudinal research project carried out to determine the long-term effects of teaching early arithmetic strategies using the Kâte counting system The sample consisted of 52 elementary school children, aged between 8 and 10 years attending Elementary 1 class from 3 different elementary schools The elementary school children's performances on 7 different numerical tasks were obtained via an individual-task-based interview Contrary to the negative view held by many parents in Papua New Guinea, the results show that the use of counting and arithmetic strategies embedded in the children's own traditional counting systems is an added advantage in their learning of formal English arithmetic strategies normally taught in schools

Most of the past mathematics curricula for the primary-aged school children in Papua New Guinea (PNG) have been based on an analysis of the steps provided by the structure of mathematics that has its roots in Western cognitive psychology (Park, 2000; Saxe, 1982; 1983; Souviney, 1983) and is interpreted according to Western, mainly Australian, curriculum models (Bishop, 1991a; 1991b; Matang, 1996)

Recent developments in mathematics curriculum reform in PNG seem to have emphasised more the role of children's thinking in their learning of mathematics, proposing a mathematics curriculum that takes into account children's own development of number concepts based on a social constructivist theory of learning (Berk, 1994; Lerman, 1989; Wheatley, 1991) While many of these curriculum reforms were aimed at pursuing improvements to both teaching and learning of mathematics in schools, they have, however, often ignored the socio-cultural aspects of mathematics education These concerns have been raised by a number of mathematics educators (e g Bishop, 2004; 1991b; Brown, Collins, & Duguid, 1989; D'Ambrosio, 1991; Matang, 1996) particularly for those children whose home and family cultures do not fully resemble the culture of the formal "western-style" education system thus contributing further to their learning difficulties in school mathematics (Matang & Owens, 2004; Seah & Bishop, 2001)

In the light of the above concerns there has been very little research carried out on the impact of culture and language on the teaching and learning of school mathematics in Papua New Guinea in the last 15 years since the early research work carried out on language and mathematics (Clarkson ,1992; Lean, Clements & Del Campo, 1990), culture and numerical cognition (Lancy, 1983; Saxe, 1981; 1982;1985; Souviney, 1983) While the traditional numeration systems of PNG have been recorded (Lean, 1992; Smith, 1980; 1981) and the elementary school curricula emphasis on culture and mathematics has recently been developed (PNGDoE, 2002; 2003), only Paraide's (2002) research has attempted an evaluation of the Lower Primary learning under the new curriculum reform There is an urgent need to combine the results of all of the above mentioned early research work to properly inform everybody concerned with mathematics education and at the same time conducting further research work on the impact of using the existing Indigenous cultural practices of mathematics or ethnomathematics (Bishop, 2004; 1991a; D'Ambrosio, 1991; 1990) in teaching school mathematics This is particularly urgent at this time when the mathematics curriculum reform is being implemented (Matang, 1996; 2002; Matang & Owens, 2004)

The current education reform strongly encourages the use of Indigenous knowledge and various local vernaculars in teaching the prescribed school subjects based on the rationale that learning is more meaningful and effective if teaching begins from the more familiar learning situations using the learner's own language (Bell, 1990; Clarkson, 1992; Paraide, 2002) While such a policy move is timely and is also supported by a number of research literatures in mathematics education (e g Berk, 1994; Bishop, 1991a; 1991b; Browns, Collins and Duguid, 1989), many parents in Papua New Guinea on the other hand have displayed strong reservations and even negative views regarding the use of local vernaculars as a medium of instruction in elementary schools claiming that it is one of the main factors responsible for lowering the standard of education in PNG

Hence in order to address the above claim by parents, the research reported here was purposely conducted to answer the main research question, "Does the use of both the Kâte language and its counting system in teaching early number knowledge enhance the learning of formal English arithmetic strategies normally taught in schools?" The analysed research data will also be used to address other pedagogical issues related to children's difficulties in learning school mathematics and assist the development of appropriate mathematics curriculum and teaching materials that are culturally relevant and inclusive

Linking the Kâte Language, Its Counting System and the Teaching of Early Number Strategies

According to Lean (1992), the Kâte language, also known in the early literature as 'Kai', is a Papuan or NAN language which has achieved considerable prominence in the Morobe Province as a lingua franca used by the Lutheran Church to carry out its Mission work extending as far as the five highlands provinces of Eastern Highlands, Simbu, Western Highlands, Enga and Southern Highlands, and part of Madang Province Hence, Renck (cited in Lean, 1992) indicated at the time of his writing that there were an estimated 75,000 people with an active knowledge of the language and a further 40,000 with a passive knowledge of it While the language is now spoken mostly by the majority of the older generation throughout the Morobe Province, the home of the Kâte language is comprised of 8 core-Kâte villages that surround the current Sattelberg Lutheran Mission station in Finschhafen District

The earliest studies of the Kâte language were by Flierl (1895) and Keysser (1925) who was the author of the first Kâte-German-English Dictionary which was extensively revised by Dr Willy Frierl and Dr Hermann Strauss resulting in the first publication of the Kâte-English Dictionary in 1977 (Frierl & Strauss, 1977) Along with other Non-Austronesian languages of PNG, the Kâte language is thought to be at least 20 000 years old (Lean, 1992)

Tylor of the University of Oxford wrote in 1871 that the practice of counting on fingers and toes lies at the foundation of our arithmetical science (in Lean, 1992) Hence, the Kâte counting system is classified as a digit-tally system (Lean, 1992) such that its counting structure includes the use of Kâte counting words for hands and feet, and both fingers and toes to symbolise counting words physically Thus, the overall structure of the Kâte counting system is a combination of the variants of both the "pair system" and the "quinary vigesimal" system It is made up of the frame pattern numerals (1,2,5,20) and cyclic pattern (2,5,20) having 2 as its primary cycle, 5 the secondary cycle and 20 a tertiary cycle (Schmidt in Lean, 1992) Hence as shown in Table 1, an analysis of the Kâte counting number words reveals that each number word is a compound of 2 or 3 single equivalent number words chosen from the set of frame pattern number words for 1, 2, 5, and 20 so that for example, 3 is a compound of equivalent Kâte number words for "two" and "one", 8 is a compound of "five", "two" and "one", 24 is a compound of "twenty", "two" and "two" and so on Thus, when this number combination principle is used, the resulting operative patterns in Kâte are illustrated by 3=2+1, 8=5+(2+1), 24=20+(2+2) and so on

Table 1
Relationship between English (Hindu-Arabic) and Kâte Numeration Systems

English numeral in figures	English number word	Equivalent Kâte number word	Kâte operative pattern for each counting number words
1	One	moc	1
2	Two	jajahec	2
3	Three	Jahec-â-moc	3=2+1
4	Four	Jahec-â-jahec	4=2+2
5	Five	Me-moc	5
8	Eight	Me-moc â jahec-â-moc	8=5+(2+1)
13	Thirteen	Me-jajahec â jahec-â-moc	13=10+(2+1)
15	Fifteen	Me-jajahec â kike-moc	15=10+5 or 15=5+5+5
20	Twenty	Ŋic-moc (ngi moc)	20 (or 20=4x5)
23	Twenty-three	Ŋic-moc â jahec-â-moc	23=20 +(2+1)

Furthermore, from Table 1 it can be noted that unlike the disjoint nature of the individual number relationships found within the English (Hindu-Arabic) numeration system, the counting structure of the Kâte numeration system is such that the use of each number word automatically provides the important number relationships between the individual counting numbers in terms of their order of occurrence in any counting tasks For example, the Kâte number word for 8 is *"me-moc â jahec-â-moc"* translated into its operative pattern is 8=5+(2+1) hence apart from emphasizing the relative sizes of the counting numbers 8, 5, 2 and 1, it also reinforces three important mathematical concepts associated with the operation of elementary addition These are firstly the *concept of addition* as an operation quantifying the counting numbers 5, 2, and 1, observing 8 as the resulting *sum* representing the total quantity of all the addends Secondly, the *order of operation* whereby the operation inside the grouping symbol "( )" indicates that this operation has been performed first In everyday counting tasks, when one counts up to 8 in Kâte, the emphasis is placed on the counting associations namely, "me-moc" and "jahec-â-moc" where the connecting letter "â" represents the idea of a plus sign (+) used in the English (Hindu-Arabic) system Thirdly, the idea of 5 as a composite unit upon which numbers between 5 and 20 are built, likewise for 20, which is a composite unit for every Kâte numeral beyond 20

From the teaching point of view, all of the above mathematical concepts are important prerequisites to learning the formal number operations of addition and subtraction normally taught in schools Hence they provide the all-important linkages between the

Kâte numeration system and the teaching of the four basic operations of addition, subtraction, multiplication and division (Matang, 2002; Matang and Owens, 2004; Park, 2000) Furthermore, the Kâte numeration system does take care of the idea of multiplication if taken either as a “repeated addition” or as a “grouping” operation On the other hand, the division operation can be very comfortably treated as representing the idea of grouping as expressed in repeated composite units (e g 15 = 5+5+5) or as an operation representing the idea of “sharing equally” Sharing is an activity that is always considered to be very important as an integral part of the cultural heritage and the value system of the Kâte people Hence it is considered as anti-Kâte not to share what an individual owns especially with those who are in need The idea of “equal sharing” is also culturally significant in the sense that when material goods are shared equally during special ceremonies it signifies equality of status that an individual person has within the Kâte hierarchy In terms of mathematics teaching, the idea of equality of any two sets is significant in the language of set theory for example, in the case of repeated composite units of 5+5+5 = 15 where each of the three composite units of 5 are all equal at the same time their sum is ‘equal’ to 15

If these links have been intuitively or formally made by the students, then students who learn basic counting strategies in Kâte should perform as well as or better than Kâte-speaking students who have begun their schooling in Tok-Pisin (the widespread lingua franca used in PNG, Pidgin-English) or English

Method

Participants

The research reported here involved a total of 52 children, aged between 8 and 10 years, attending Elementary 1 (E1) class from 3 different Elementary Schools within the Kâte-speaking language area of Finschhafen District in Morobe Province, Papua New Guinea The total number of participants represented the total number of children in each E1 class These are School A (N=17) and School B (N=17) where all classroom teaching is conducted in the Kâte language, whereas School C (N=18) is located at a Mission station and all its classroom teaching is conducted mainly in Tok-Pisin and some English although 90% of the children are native Kâte-speakers The remaining 10% is made up of children whose parents work for the Lutheran Mission having originally come from other parts of the country including those children born into families having parents who come from at least two different language groups All three schools are located within a maximum radius of about 1-hour walking distances of the children’s homes Unlike Schools A and C which are both located along the coast with easy access to the provincial road network system, School B is located further inland accessible only by about 4-5 hours of walking distance from the main road junction where School A is located Hence the children do not have that much exposure to everyday interactions with people from other parts of the country including the basic government services compared to those children attending Schools A and C Schools A and B are located right in the heart of the Kâte-speaking language area but in two different villages hence all classroom teaching is conducted in the Kâte language including the translation of both the PNG National Pledge and the singing of the Country’s National Anthem

Instrument

The main research instrument used in this research is the modified version of the *Schedule for Early Number Assessment* (SENA) taken from the Australian school text *Count Me in Too* used in the NSW schools (NSW DET, 2002) Though the instrument initially had 8 different numerical tasks, only 7 of these are used to compare the performances of children from all 3 schools These numerical tasks are namely, *Forward number word sequence (FNWS), Backward number word sequence (BNWS), Subitising, Counting, Addition, Subtraction,* and *Multiplication/division* with each numerical task having at most 3 separate interview tasks giving a total of 15 interview tasks for each participant (see Table 2)

Procedure

The main data-collection method involved interviewing each individual child on each of the 7 numerical tasks by the author, who is also a fluent native Kâte-speaker, firstly in Kâte and then later in English Responses on each of the 15 interview tasks for the 7 numerical tasks were recorded individually With the exception of the children in E1 class from School C where all interviews were conducted only in English, all children in both Schools A and B were interviewed individually firstly in Kâte followed by English with each child also responding in the same language order for each of the 7 numerical tasks The author also made observation notes on the type of counting strategies that each child used in arriving at a particular answer or response during each interview session for each numerical task, noting if each child used the straight mental calculation (MC), finger counting (FC), or verbal counting (VC)

In order to answer the main research question stated earlier, each question or interview task under each of the 7 numerical tasks (see Table 2) were given a score of one (1) hence the highest number of possible correct responses that each student participant was expected to score is 15 or 100% performance rate That is, the closer a student's score is to 15 the higher is the participant's overall performance for all 7 numerical tasks On the other hand the highest possible total score for School A and B is 255 (i e 15x17 students) or 100% performance rate, whereas for School C it is 270 (i e 15x18 students) In other words, the closer it is to highest possible scores of either 255 or 270 for each participating school, the higher is the performance rate for each school

Results and Discussion

An analysis of children's overall mean performances (see Table 2) for all seven numerical tasks in English indicate that there is no significant difference between each of the three schools This result is supported by the one-way ANOVA test with *p*-value greater than 0 05 and the post-hoc Scheffe test indicated that there was no significant difference between each of the three means This result is also supported by overall performances of each school where School A scored 72% (184/255), School B scored 71% (181/255), and School C scored 72% (194/270)

In terms of paired data comparison between combined Schools A and B against School C (i e Kâte versus Pidgin-English), there is also no significant difference between the two overall means of 71 6% and 71 9% respectively Though based only on one set of data, it is however reasonable to say that at least for those children learning early number knowledge in Kâte language using its counting system (Schools A and B) are not in any way disadvantaged in learning the formal English arithmetic strategies normally taught in schools when compared to School C children not taught in Kâte

Table 2
Total School Performances for Numerical Tasks in Kâte and English

No Strategies	FNWS		BNWS		Subitise		Count		Add		Subtract		Multiply		Overall	
Language	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN	KT	EN
No of Sub Tasks	3	3	2	2	1	1	3	3	2	2	3	3	1	1	15	15
Sch A (n=17)	49	48	19	18	16	16	45	44	19	18	29	29	11	11	188	184
Sch A %	96	94	56	53	94	94	88	86	56	53	57	57	65	65	74	72
Sch B (n=17)	37	39	20	23	14	16	48	49	22	21	25	25	7	8	173	181
Sch B %	73	76	59	68	82	94	94	96	65	62	49	49	50	57	68	71
Sch C (n=18)	NA	49	NA	25	NA	16	NA	48	NA	24	NA	21	NA	11	NA	194
Sch C %	NA	91	NA	69	NA	89	NA	89	NA	67	NA	39	NA	61	NA	72
Overall %	84	87	57	63	88	92	91	90	60	60	53	48	57	61	71	72

Note: FNWS = Forward Number Word Sequence BNWS = Backward Number Word Sequence
KT = Kâte EN = English NA = Not applicable

Comparing the performances of each E1 class on individual numerical tasks in English (see Table 2), School A performed better than the other two schools in FNWS (94%), Subtraction (57%) and Multiplication/Division tasks (65%) While both Schools A and B had the same performance level, both higher than School C, on the Subitising tasks (94%), School B performed better than the other two schools on the counting tasks scoring 96% On the other hand School C performed better than the other two schools on BNWS (69%) and Addition (67%) It is significant to note that on average all three schools did not perform well above the 60% mark on the subtraction tasks with each school scoring 57%, 49% and 39% respectively compared to their performances on the other numerical tasks This result in many ways is not surprising since the majority of the everyday counting tasks of the Kâte people mainly involve counting or addition tasks rather than the subtraction tasks hence supporting the claim by Brown, Collins, and Duguid (1989, p 32) that, "knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used "

Since this is the first of a series of an ongoing longitudinal research project that will further verify the above result, it is however important to note that it provides information that has significant teaching implications for mathematics education in PNG in terms of children's acquisition of mathematical knowledge That is, the result somewhat challenges the current dominant psychology of mathematics learning that uses the analysis of steps provided by the structure of mathematics in developing the many mathematics curriculum dominated by the view that mathematical knowledge is independent of any culture and its value system (Brown, Collins, & Duguid, 1989; Park, 2000; Bishop, 2004) As an alternative to the current culture of mathematics learning, Brown, Collins, & Duguid (1989) propose a cognitive apprenticeship that honours the situated nature of knowledge Hence they further argue that "many methods of didactic education assume a separation between knowing and doing, treating knowledge as an integral, self-sufficient substance, theoretically independent of the situations in which it is learned and used" (p 32)

An analysis of the *t*-test results performed on the paired data sample for each of the children from both School A and School B (see Table 3) reveals a high correlation between children's performances on each of the 21 interview tasks for the 7 numerical tasks in Kâte and English The result basically indicates strong relationships between children's performances in Kâte and English in that if a child performs well in Kâte there is a good chance that she/he is most likely to also perform well in English In the context of mathematics teaching, the result is significant in that it supports that students who learn in their vernacular will perform the basic arithmetic strategies well in English

Table 3
Paired Sample Correlation of Children's Performances between Kâte and English

School	N	Correlation	Significance
A	17	0 992	0 00
B	17	0 921	0 00

Conclusion

Though the research results reported here are limited to only 3 elementary schools in the Kâte-speaking language area of Morobe Province at one specific time and hence it is not conclusive, the results are significant in that they provide support for the value of local vernacular languages and the Indigenous counting systems in teaching early number strategies in elementary schools in Papua New Guinea This is contrary to the popular view held by many parents in Papua New Guinea While the preliminary discussion in this paper suggests why students will satisfactorily learn English arithmetic strategies, further research is needed to confirm this and to find out how teachers can best use the vernacular counting systems to improve their teaching of arithmetic strategies in English

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